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A STATUS REPORT ON THE UTILIZATION OF FREEZING IN DEWATERING OF SLUDGES*

by

J. B. Farrell**

Freezing has been found to produce remarkable changes in some aqueous sludges which have greatly improved their dewaterability. This report summarizes past findings and forecasts whether freezing will see substantial commercial application in dewatering of sludge.

The Nature of Sludges

The term sludge is associated in "Roget's Thesaurus" with words such as ooze, mud, slime, and jelly. For those with the responsibility for dewatering sludges, the association is apt. Sludges are usually superficially homogeneous. Suspended solids are often colloidal or are soft and easily deformed. Two types of sludge of common experience are the residues left behind when water is treated to produce municipal water supplies and when sewage is treated to remove contaminants.

The troublesome part of waterworks and sewage sludges is their suspended solids content. Soluble solids are either no problem or are relatively easy to handle. The sludges resist gravity settling and their suspended solids content is low (from 0.5 to 10 percent). Characteristically, they pass through or clog filters. When they are filterable, rates are low. Addition of inorganic chemicals or polymeric electrolytes, referred to as conditioning agents, can cause coagulation, and filtration will be improved. Costs for such conditioning often outweigh all other costs of dewatering, including equipment amortization.

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The Effect of Freezing

The effect of a freeze-thaw sequence on certain types of sludges is often remarkable. Doe, Benn, et al[1], report that a gelatinous waterworks sludge, formed by treatment of a surface water with aluminum sulfate, can be converted into a clear effluent and particulate matter which settles readily. Agitation does not resuspend the particles in the sludge.

The ingredient which gives most waterworks sludges their gelatinous character is aluminum hydroxide. When an aluminum salt is added to a large excess of water, the salt hydrolzes and forms a flocculent precipitate of aluminum hydroxide. The flocculent nature of the precipitate, so important to its function of clarifying water, makes it hard to dewater. Ferric salts behave in the same manner when added to water.

When a hydroxide floc is chilled and freezing commences, pure ice crystals form. The hydroxide floc is rejected since it cannot enter into the crystalline structure of the ice. The floc particles are moved into contact with each other by the growth of crystals. It is this writer's opinion that water associated with the hydroxide floc becomes part of the ice crystal structure. The hydroxide particles, now in close proximity, bond to one another and grow to a size which can settle readily. Fast freezing does not produce the same effect because the individual hydroxide particles have not been brought together. When fast-frozen sludge is thawed, the water of hydration is again incorporated into the structure of the hydroxide particles.

Clements, Stephenson, et al[2] carried out an extensive investigation of the effect of freezing on sewage sludge. The most noteworthy difference between these sludges and hydroxide sludges is that vigourous stirring returns

sewage sludge to its poorly filterable state. Freezing causes agglomeration of sludge particles which is evident when the sludge is thawed. Agglomerated clumps, which are interspersed with spaces filled with clear water, resist dispersion to some degree, and the free water can be drained off very easily. Additional moisture can be removed by applying a vacuum. Final moisture content is comparable to that obtained in vacuum filtration, with chemical conditioning, but production rates per unit of filtering surface are far higher.

Application to Hydroxide Sludges

British investigators have successfully applied the freezing process to dewatering of waterworks sludges. Doe, Benn, et al[1] review their development work which led to a successful freezing process. In a recent publication, Benn and Doe[3] observed that besides the three plants constructed in Great Britain, plants utilizing sludge freezing have been built in Japan and Germany.

A schematic process flowsheet adapted from Benn and Doe[3] is shown in Figure 1. Ammonia vapor is removed from a suction vessel, compressed, and condensed inside tubes in a tank filled with sludge frozen in an earlier cycle. The condensed refrigerant returns to the suction vessel. Refrigerant, now under low pressure, is circulated to closely-spaced tubes in a second tank filled with fresh sludge. Evaporation of the refrigerant freezes the sludge. When the sludge in the first tank is thawed, and the sludge in the second tank frozen, a cycle is complete. The thawed sludge is removed and replaced with fresh sludge. Valves on the refrigerant lines are adjusted and the frozen sludge becomes the condenser for refrigerant vapor. The cycle is now ready

to recommence.

A most serious problem that had to be met in the process development was the need to develop a freezing vessel which did not fail after a relatively few cycles. Benn and Doe[3] describe a number of vessel designs. In one successful modification, vessel walls and the tubes in a vertical bundle were slightly tapered to be closer together at the bottom. Consequently, the sludge froze solid at the bottom first. A brine-filled bag, connected to a constant head tank, was placed in the upper half of the freezing vessel to allow for expansion of the sludge as it froze.

The electrical energy requirements for freezing were low. The lowest figure quoted by Benn and Doe[3] was 118 kwhr per 1000 U. S. gallons for the most efficient plant, although figures were 170 kwhr/1000 U. S. gallons at another plant. Costs including labor, electricity and amortization at 10 percent per year amount to about $5.20 per thousand U. S. gallons. These figures do not include cost for a building.

The cost of the freezing process depends on the volume of water to be frozen. It is vitally important to get as concentrated a sludge as possible for a feedstock.

In cold climates, the cost of refrigeration plant and energy can be eliminated if natural freezing can be properly managed. Farrell, Smith, et al[4] have collected data on natural freezing and suggested design procedures. These authors discovered that the most important variables are snow cover and (obviously) the amount of cold weather. Freezing in thin layers is recommended, because it is essential to freeze completely. Snow cover may be removed by plowing or, if not deep, by flooding with water or sludge.

Sewage Sludge

The effect of freezing on sewage sludge was investigated in depth by Clements and coworkers[1,5]. These workers eventually built a one ton per day can-ice plant to produce enough sludge for pilot-scale investigation of the dewatering process. Difficulty was encountered in dewatering the sludge conditioned by freeze-thaw method. A vacuum filter did not work- the filter cloth blinded quickly. A home-made band filter was easier to keep from blinding. Monofilament fibers worked better than a fabric woven from staple. The work on sludge freezing was apparently abandoned since there are no further reports in the literature.

Katz and Mason at Rex-Chainbelt[6] reported work that indicated exceptionally good results with activated sludge from Milwaukee's wastewater plant. They proposed that the sludge be dewatered on a screen filter which would be less likely to blind than cloth-covered filters. Geinopolos[7] continued this investigation. This group experimented with direct refrigeration with immiscible refrigerants, and with freezing by flowing sludge onto a cold plate. However, the desired conditioning effect could only be achieved by indirect refrigeration in which non-flowing sludge was frozen relatively slowly and completely. Addition of ferric chloride allowed shorter freezing times for a given effect.

Their studies indicated that storage of the activated sludge after it was generated in the sewage treatment process reduced the value of the freeze-thaw conditioning. As a consequence, they chose to consider continuous freezing rather than a batch process. Freezing on a steel belt cooled from underneath by chilled brine seemed to offer minimal processing difficulty and a high degree of operating flexibility.

Costs were estimated for a plant which included the following processing steps:

addition of a small amount of ferric chloride to the sludge

freezing of a 1/2-inch layer on a steel belt in 90 minutes

thawing and dewatering the sludge on a screen filter

Operating costs, including chemical costs, but excluding amortization were approximately the same for the entire dewatering process when compared to dewatering by conventional chemical conditioning followed by vacuum filtration. However, the slow freezing rate required a large freezing area which was both space-consuming and very costly. When the large capital cost for the freezing equipment was included in the operating cost, freeze-thaw conditioning was not even remotely competitive with conventional processing.

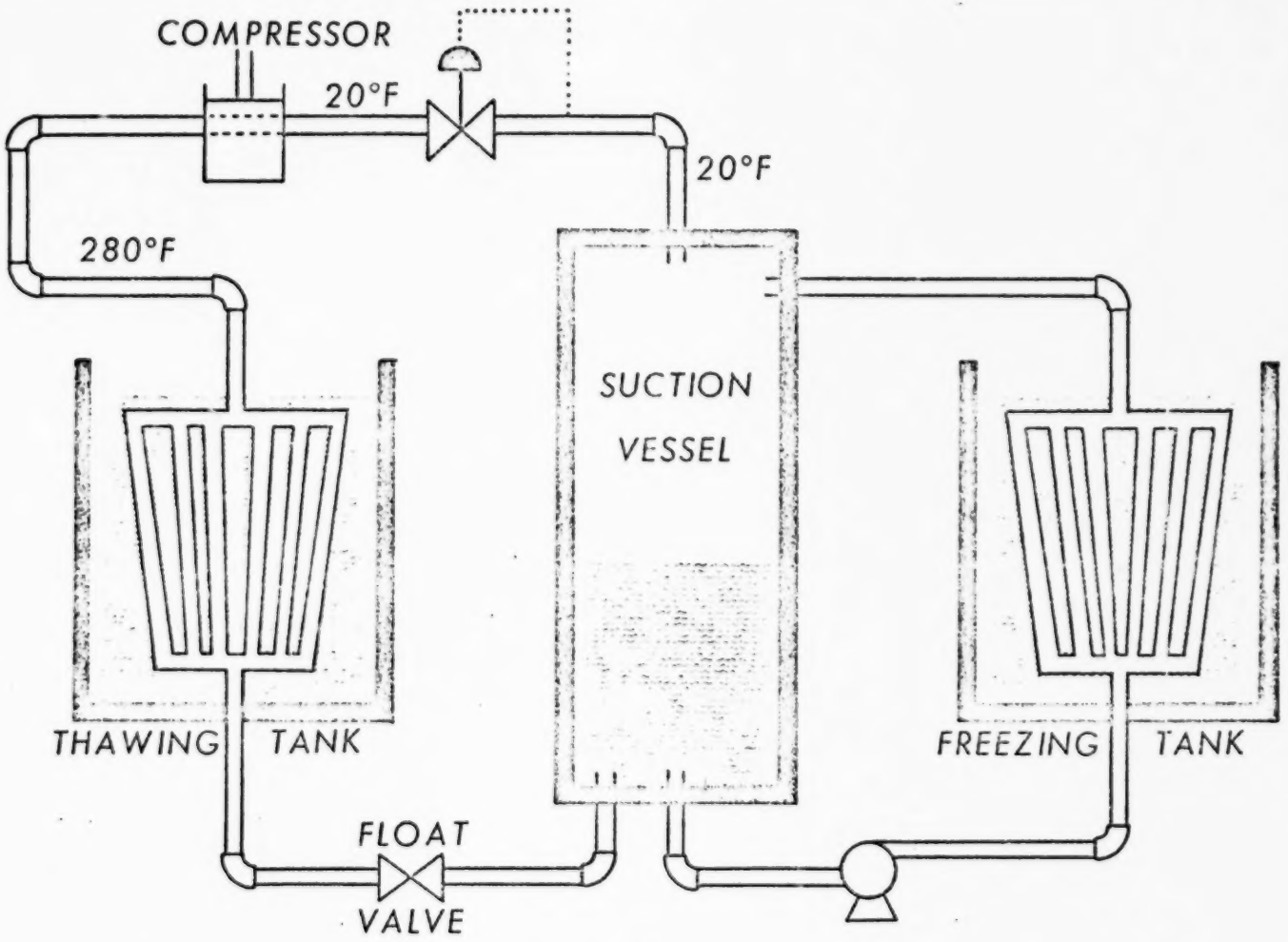
Cheng, Updegraff, and Ross[8] obtained results with sewage sludge which indicate that high-rate freezing at small temperature differences produces the desired changes in sludge characteristics, provided chemicals are present. This writer has observed[9] that surface area requirements are still quite large.

Limitations of Freeze-Thaw Conditioning

Attempts to advance the technology of freeze-thaw conditioning by direct refrigeration or partial freezing have not been successful. Continuous freezing on a belt conveyor is too costly. Cyclic batch processing is the only proven method available and has only been demonstrated for dewatering of waterworks sludge. Costs are not much better than for competitive processes such as conventional filtration. Natural freezing can be carried out in cold climates, but it probably cannot be used for sewage sludges.

Freeze-thaw conditioning is greatly limited by the need to freeze slowly. Applications might increase greatly if a heat transfer surface could be developed which would be inexpensive, utilize little floor space, not be easily clogged by sludges, and which would not be damaged by repeated freeze-thaw sequences.

FIGURE 1
SCHEMATIC DIAGRAM OF SLUDGE FREEZING PLANT



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